Multilayer mirrors for EUVL, status progress

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Outline

- Collector optics
- Illuminator optics
- Thermal stability
- Substrates ion beam polishing
- Barrier layers for La/B_4C
- Conclusion

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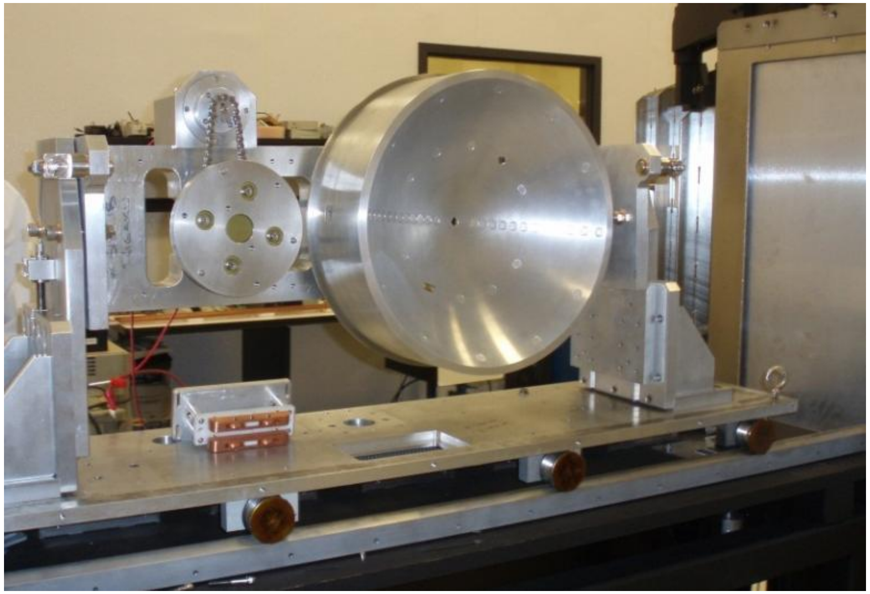
Collector optics deposition



- Vacuum (load-locked)
  - 10^{-8} ultimate
  - 10^{-9} water
  - 15min from atm to 10^{-6}
- Process
  - 5 planar magnetron (RF,DC)
  - 4 process gases
  - 0.5 to 5 mTorr
  - linear ion source
  - 20-100 particles/cm^2 on optical surface

- Dual Spinning Capability
  #1: 550mm dia x 220mm thick
  #2: 175mm dia x 35mm thick
  (Compatible with velocity motion control)
- Mechanical
  - 500 x 1500mm carrier (2)
  - 0.2mm accuracy
  - 1-133 mm/sec (±0.1%)
  - velocity profiling (6 pts/mm)

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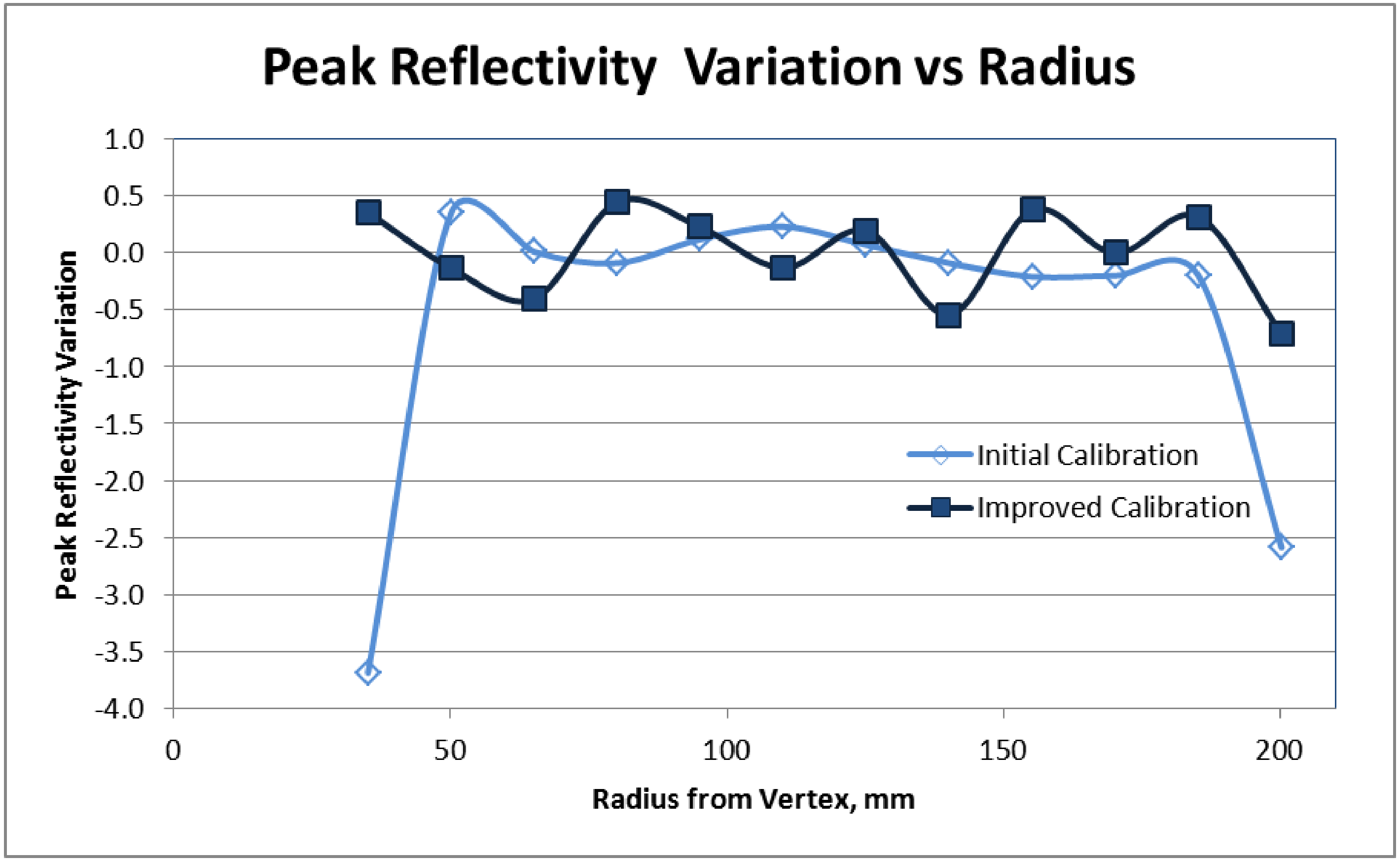
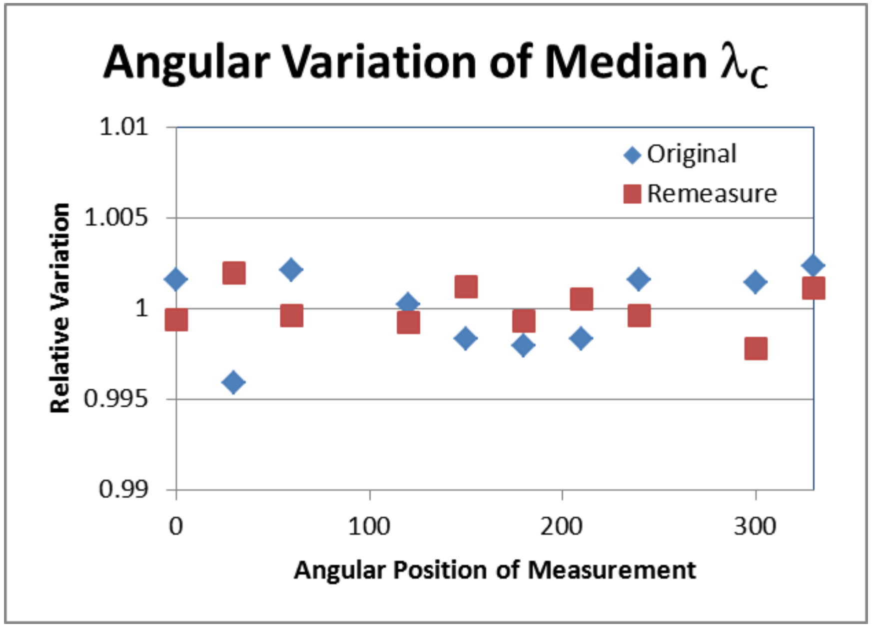
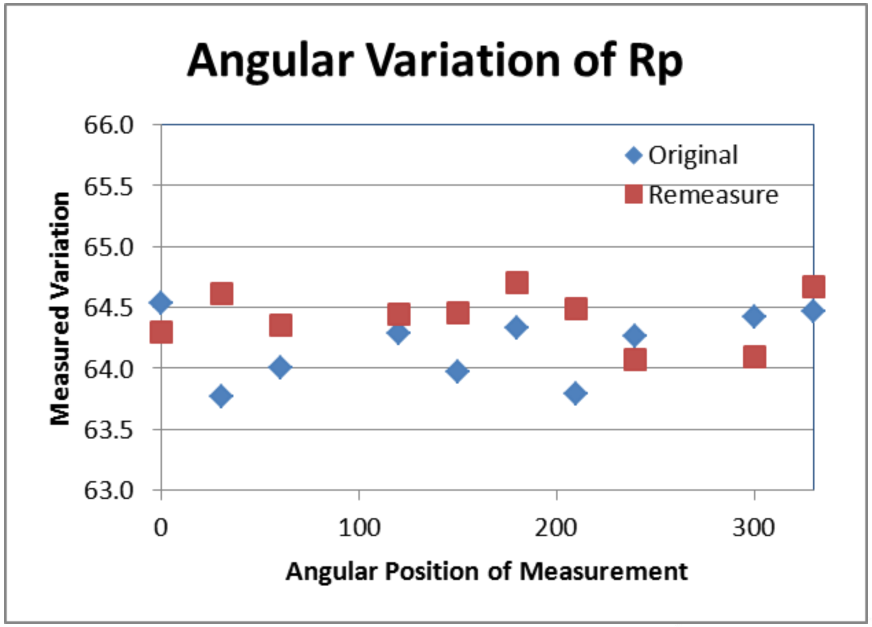
Radial variation of Reflectivity Performance has been improved



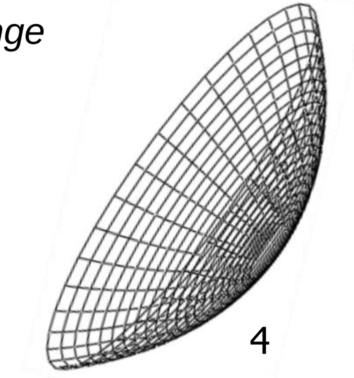
Angular variation at a fixed radius is within tolerance of the measurement



±0.25% full PV range

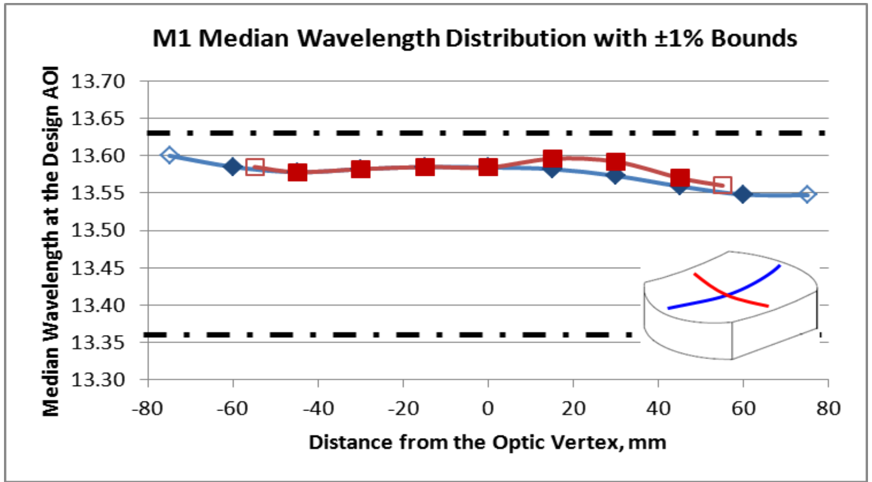


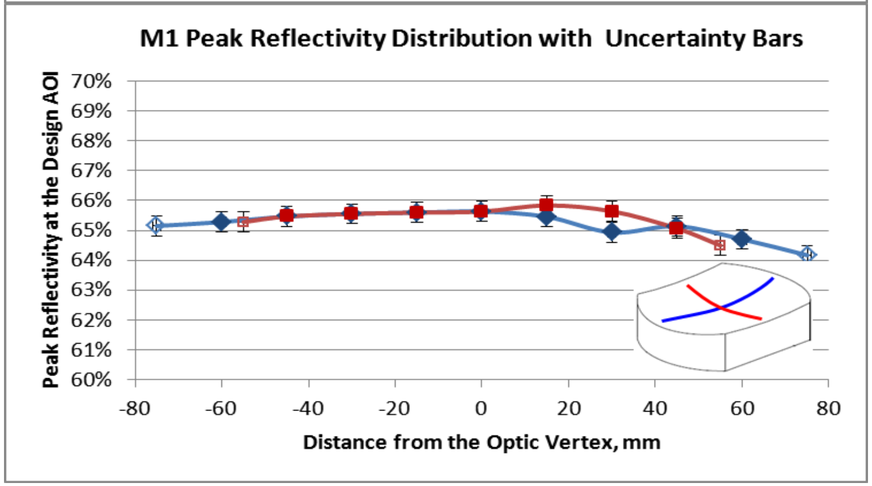
±0.35% full PV range



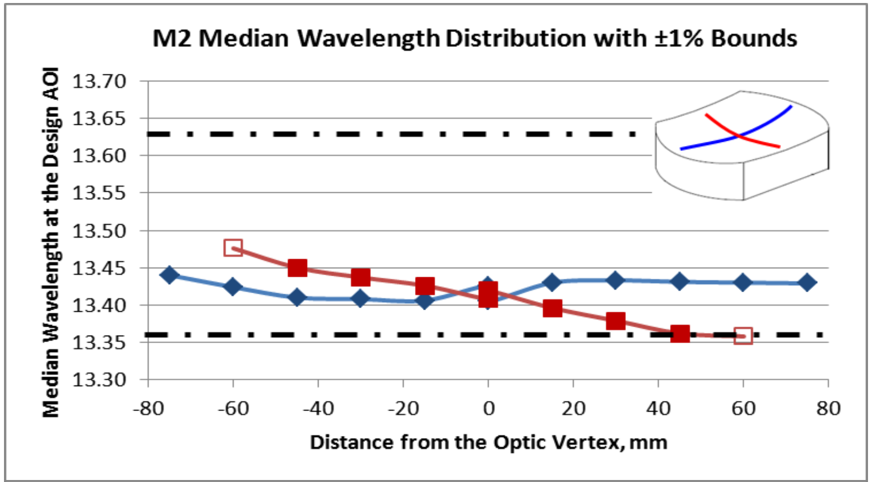
EUV measurement results

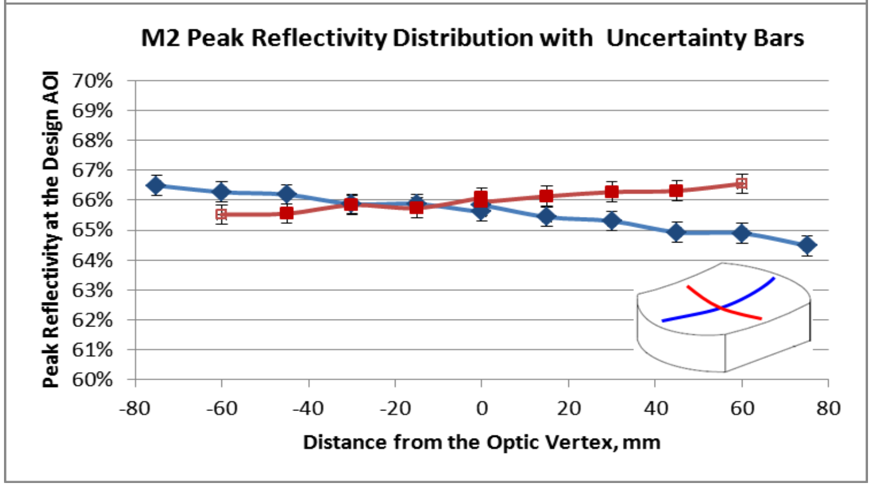
M1





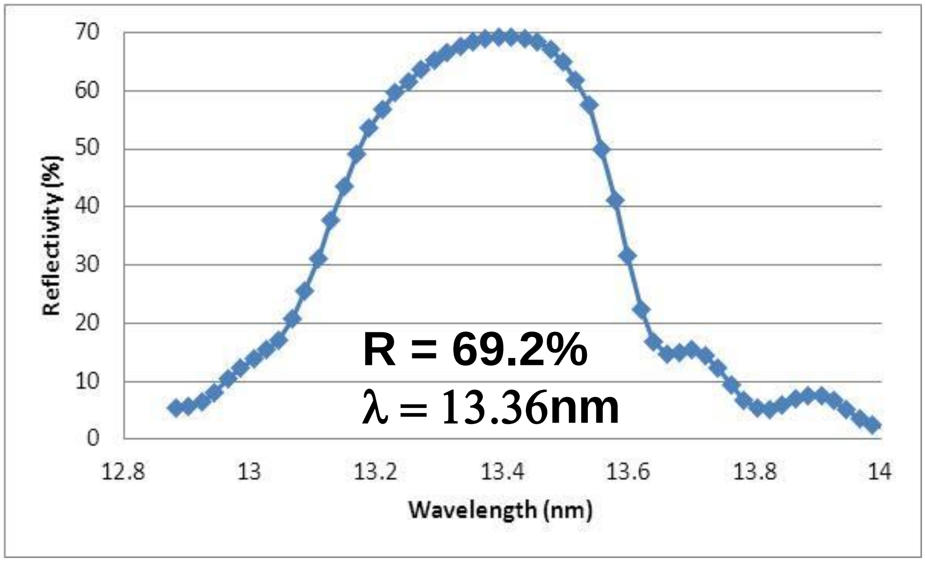
M2



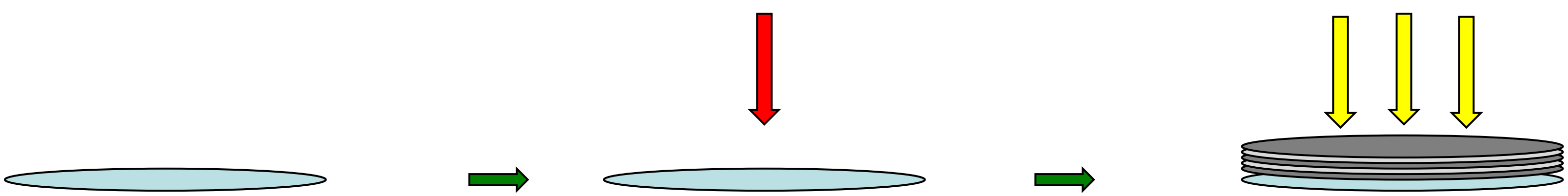


EUV measurements were done at CXRO and NIST

Improvement by substrates polishing



69.2% vs 68.7%

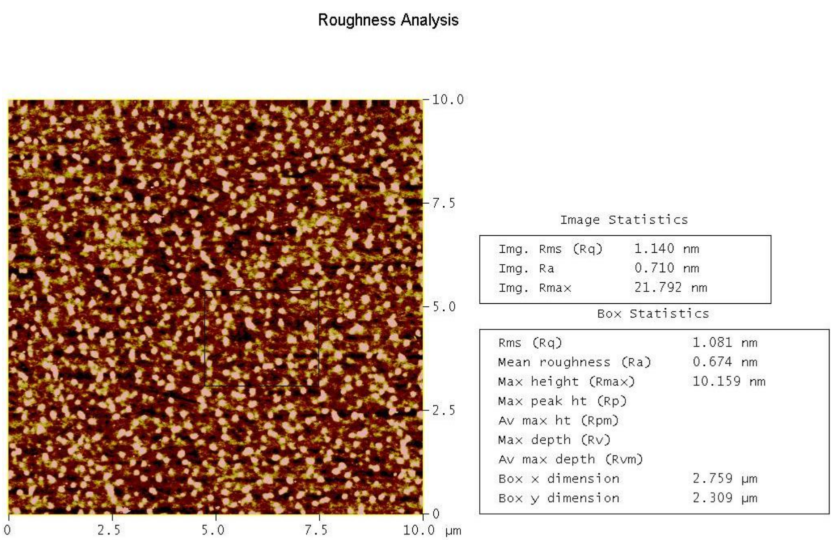


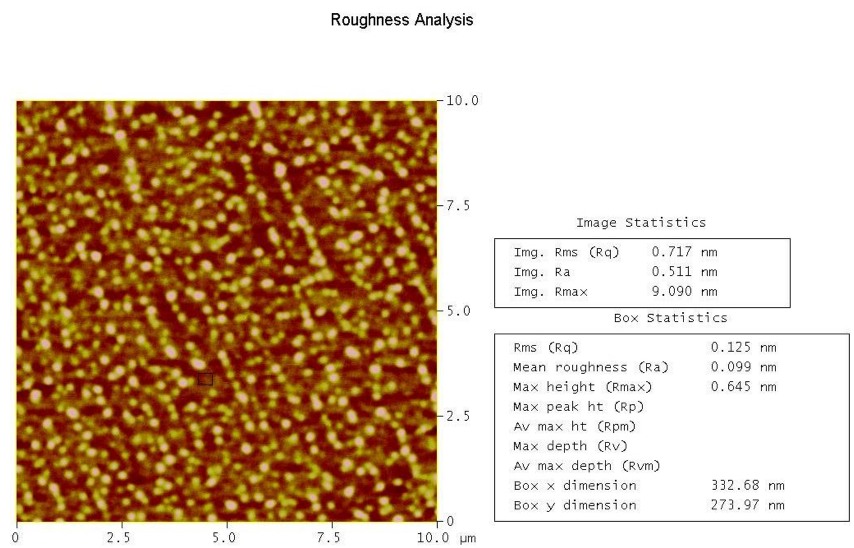
Regular Wafer
(AFM RMS=1.5A at 10µm)

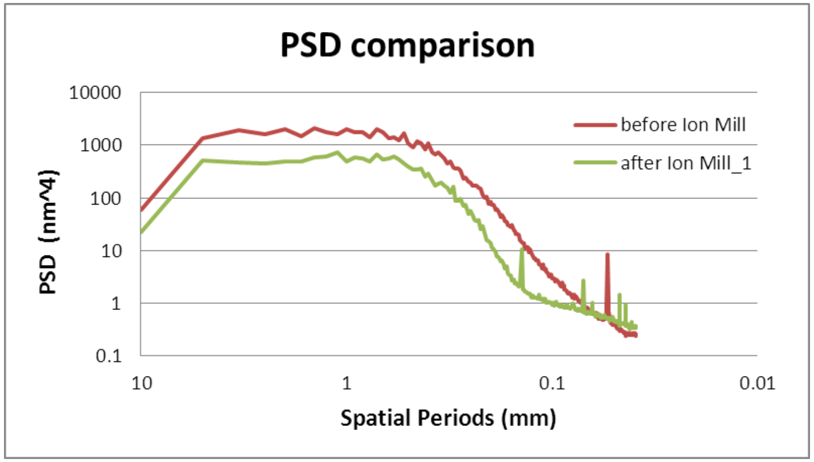
Ion Mill treatment
(AFM RMS=1A at 10µm)

Mo/Si multilayer

Substrate smoothing: Sample 1







Spatial periods	RMS Roughness
>1 mm	11Å ⇨ 7Å
<1 mm	10Å ⇨ 1.2Å

Substrate smoothing: Sample 2

Roughness Analysis

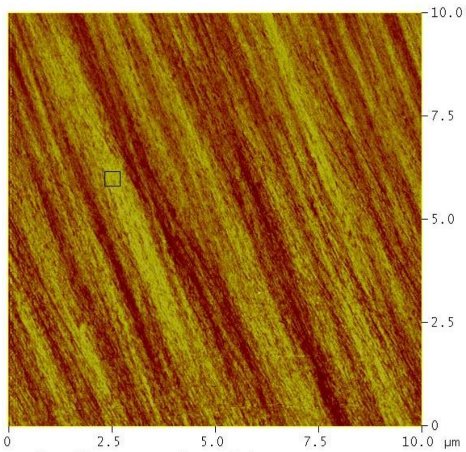


Image Statistics

Img. Rms (Rq)	0.381 nm
Img. Ra	0.304 nm
Img. Rmax	4.103 nm

Box Statistics

Rms (Rq)	0.218 nm
Mean roughness (Ra)	0.173 nm
Max height (Rmax)	1.256 nm
Max peak ht (Rp)	
Av max ht (Rpm)	
Max depth (Rv)	
Av max depth (Rvm)	
Box x dimension	371.82 nm
Box y dimension	352.25 nm

Roughness Analysis

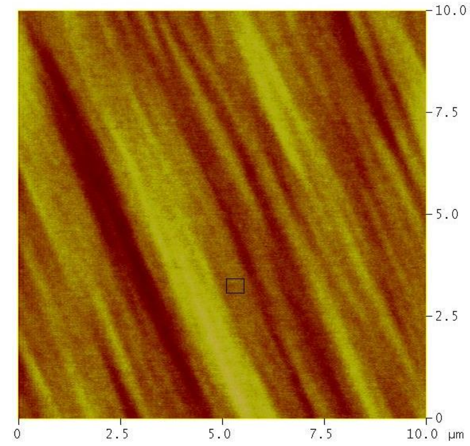
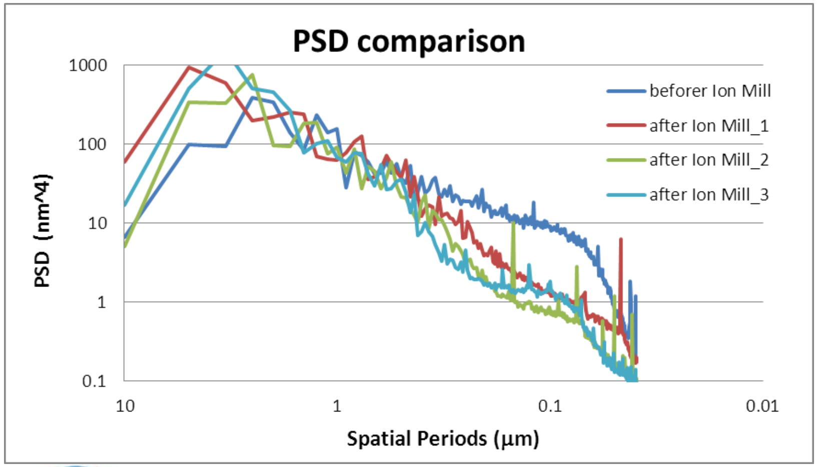


Image Statistics

Img. Rms (Rq)	0.402 nm
Img. Ra	0.312 nm
Img. Rmax	2.808 nm

Box Statistics

Rms (Rq)	0.107 nm
Mean roughness (Ra)	0.086 nm
Max height (Rmax)	0.618 nm
Max peak ht (Rp)	
Av max ht (Rpm)	
Max depth (Rv)	
Av max depth (Rvm)	
Box x dimension	430.53 nm
Box y dimension	352.25 nm

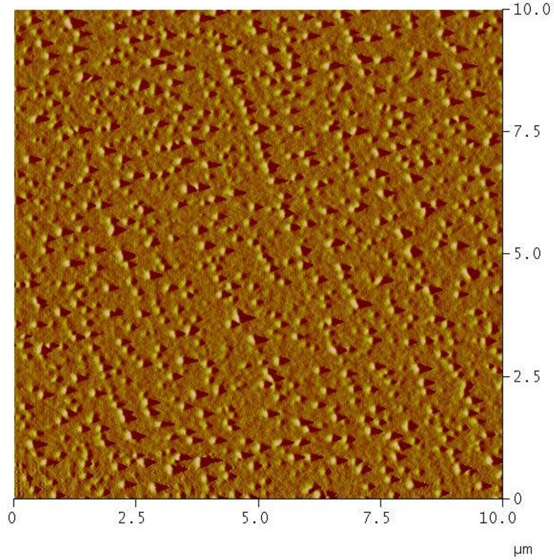


Spatial periods	RMS Roughness		
>1 mm	4Å	→	4Å
<1 mm	2Å	→	1Å

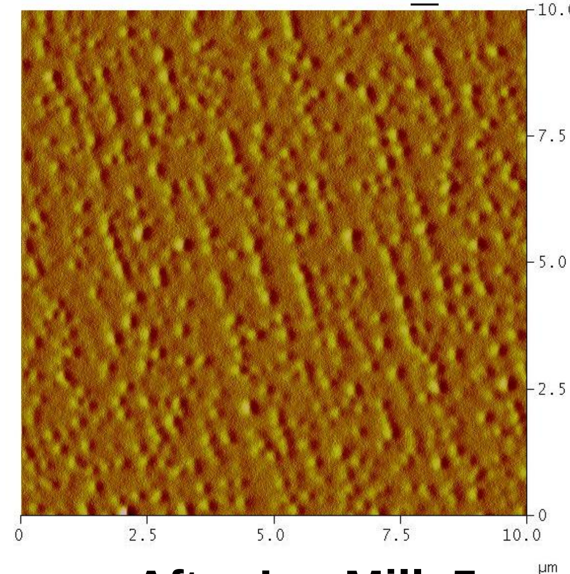
Ion beam polishing

“Dark field’ imaging: Sample 1

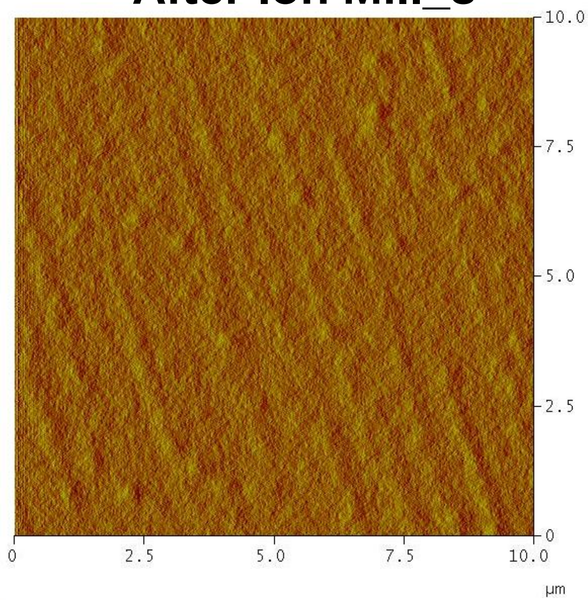
Before Ion Mill



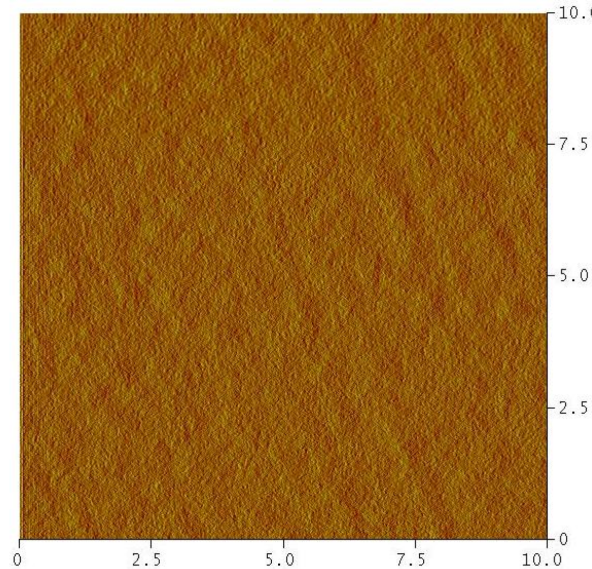
After Ion Mill_2



After Ion Mill_3

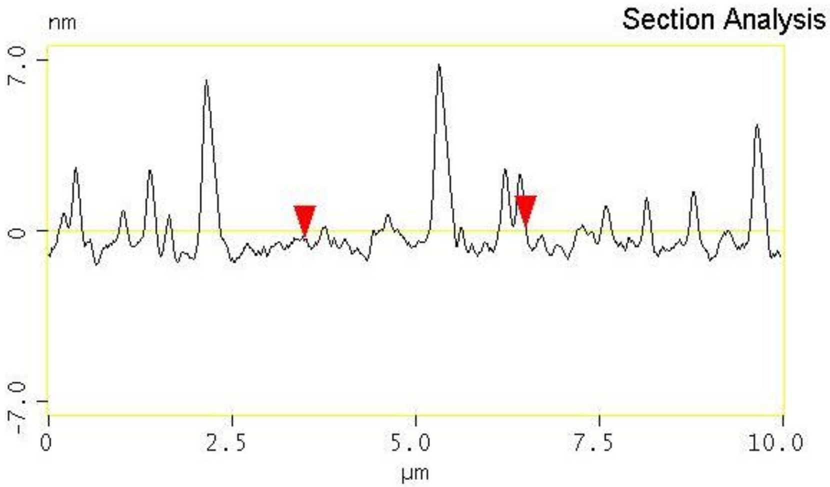


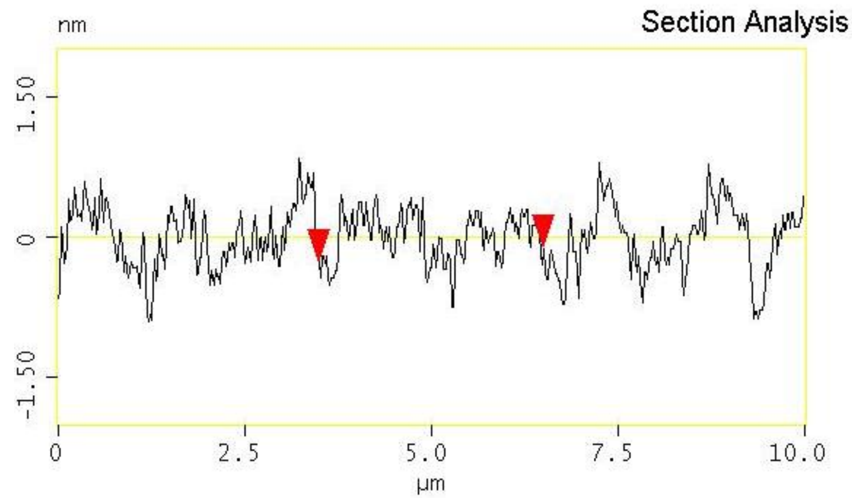
After Ion Mill_5

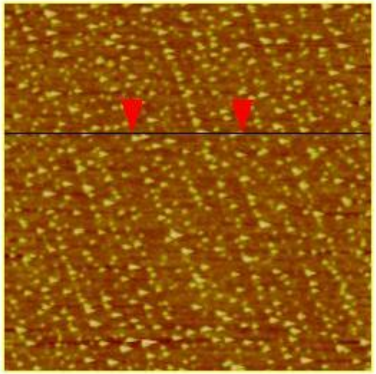


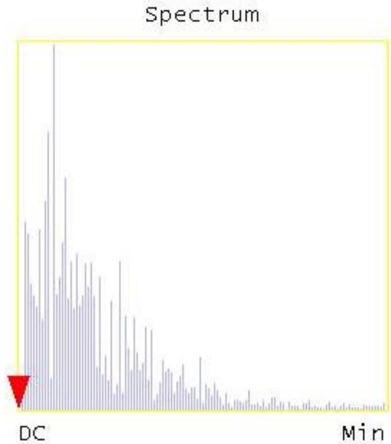
Ion beam smoothing

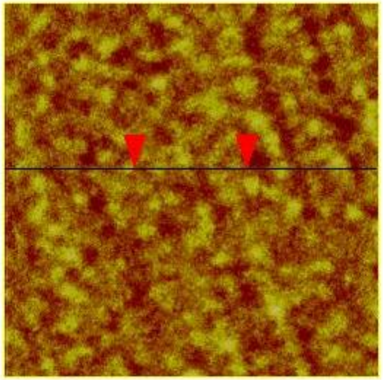
PV smoothing: after Ion Mill_5

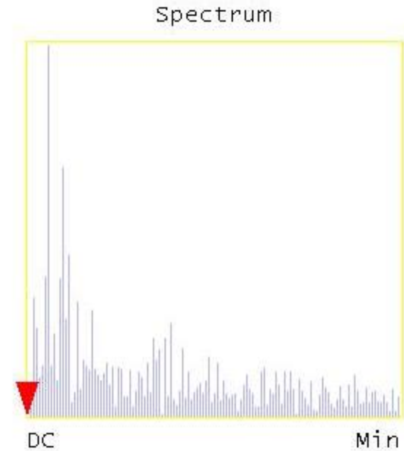




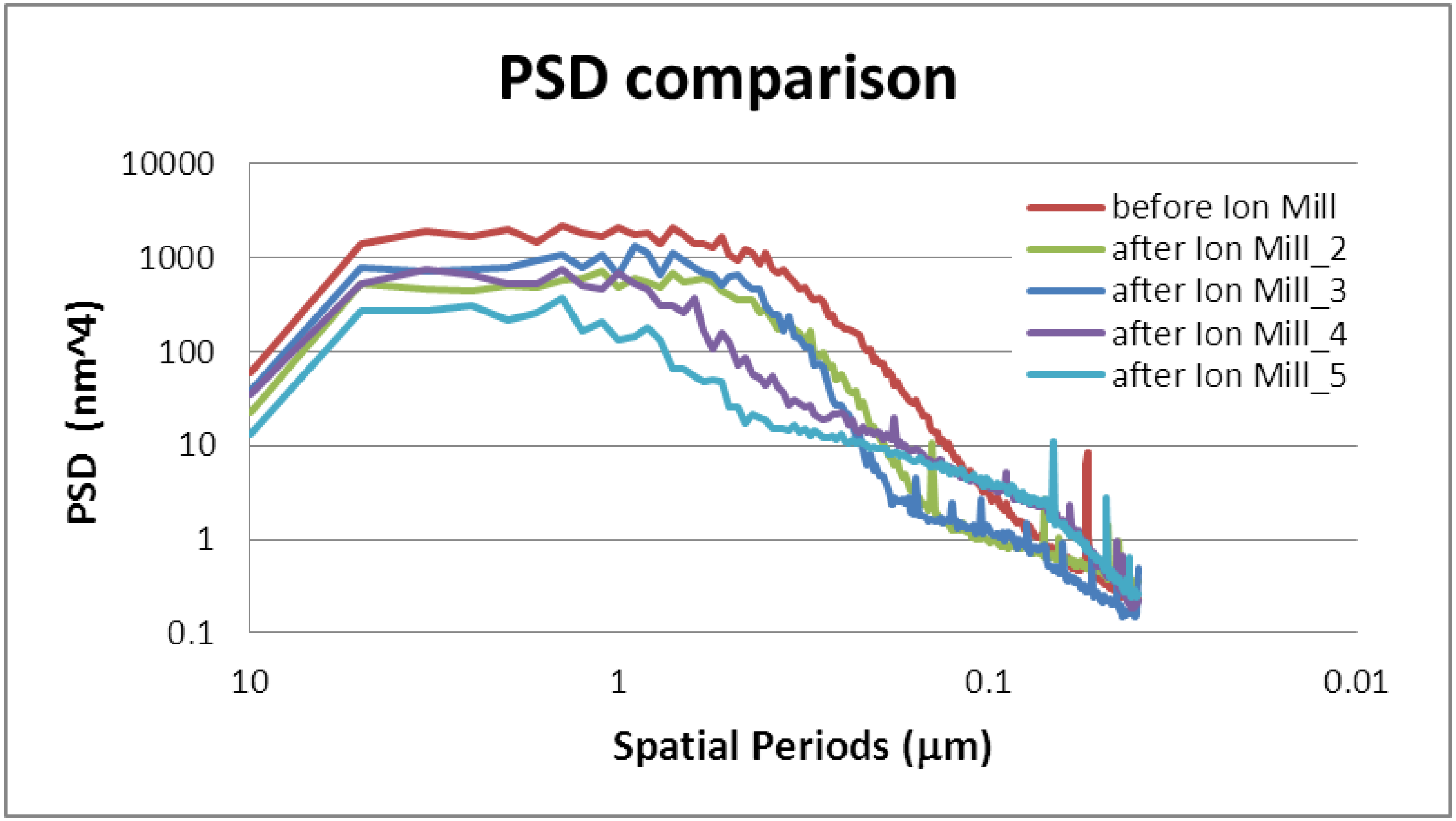








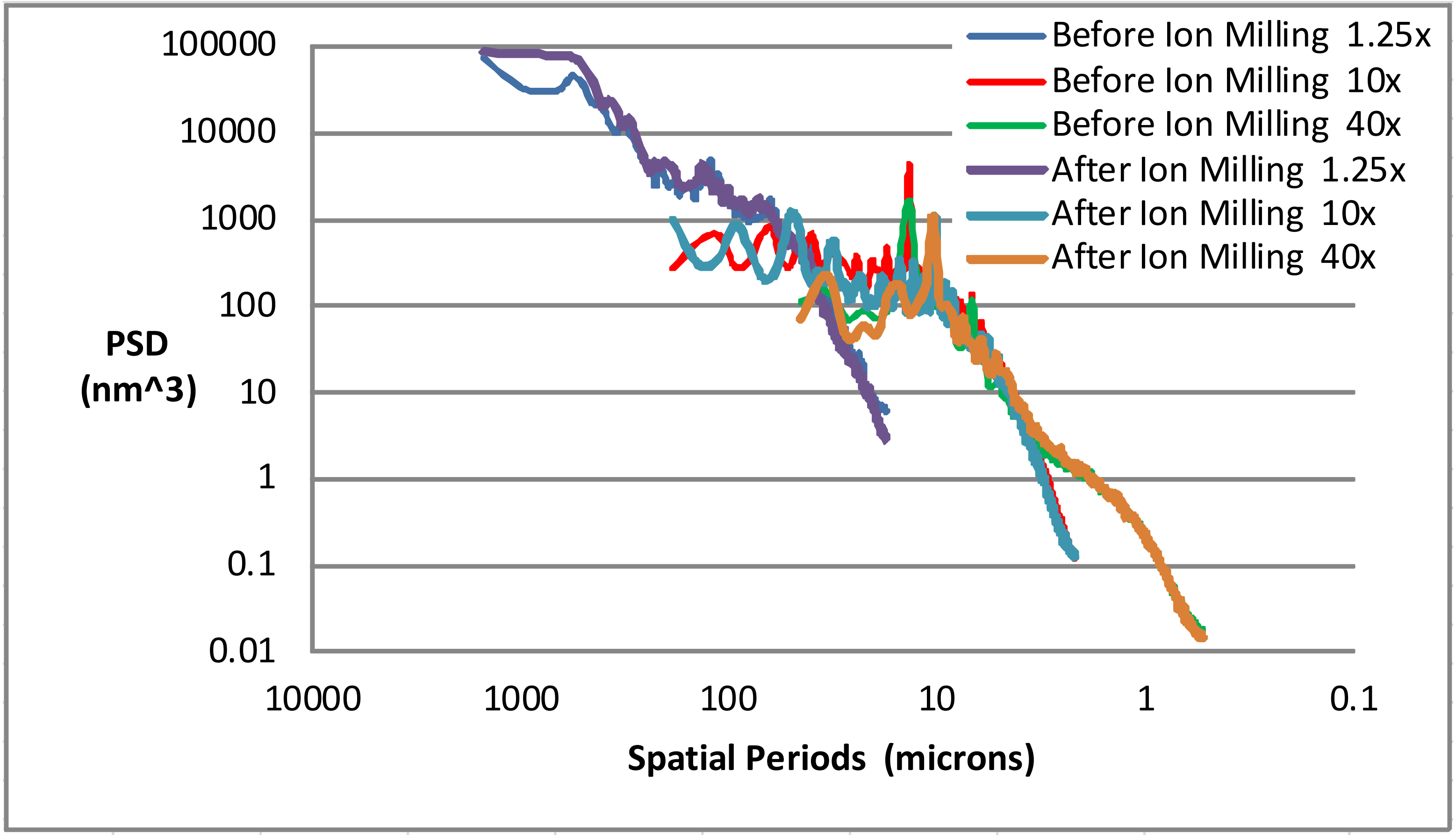
High Spatial Frequencies Roughness



Change in HSFR depends on polishing process

Ion beam smoothing

Mid Spatial Frequency Roughness



No change in MSFR

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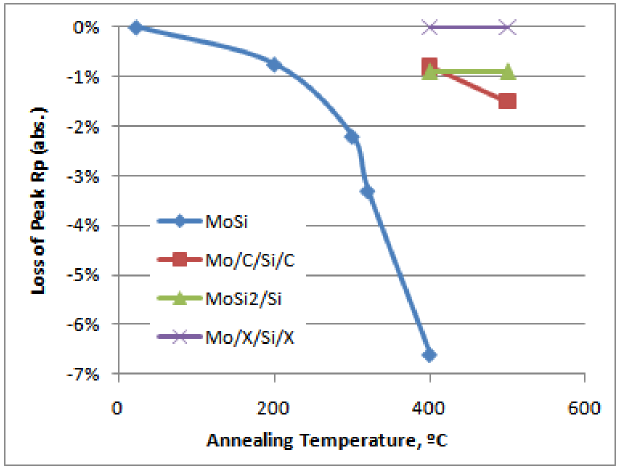
Thermal stability

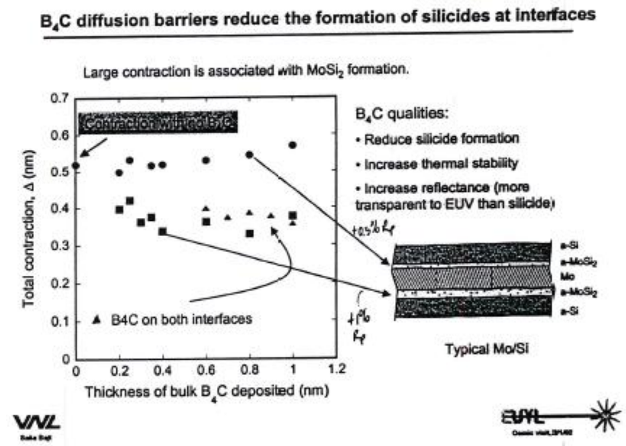
Materials choice

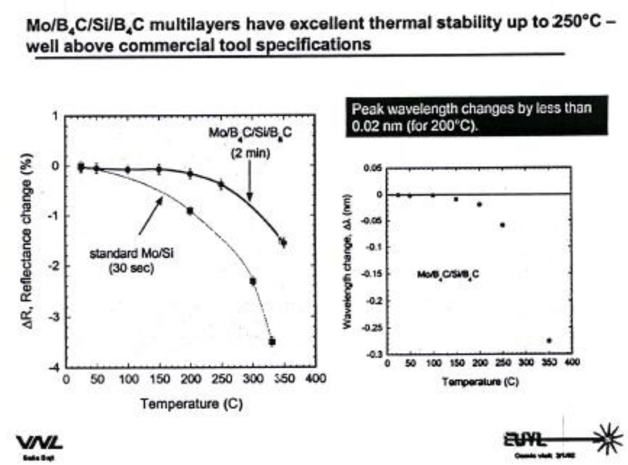


System	Temperature range	$R_{13.5\,nm}$ %	FWHM, nm
$MoSi_2/Si$	≤ 500°C	41.2	0.26
Mo/C/Si/C	≤ 250°C	59.6	0.54
$Mo/X_1/Si/X_1$	≤ 400°C	60.0	0.49
$Mo/X_2/Si/X_2$	≤ 500°C	58.8	0.50

Mo/Si taken from: C. Montcalm, Eng. Opt. 40, 469 (2001)
others from: S. Yulin, SPIE 5751, 1155 (2005)

Barrier layer





Reflectance and stability improvements

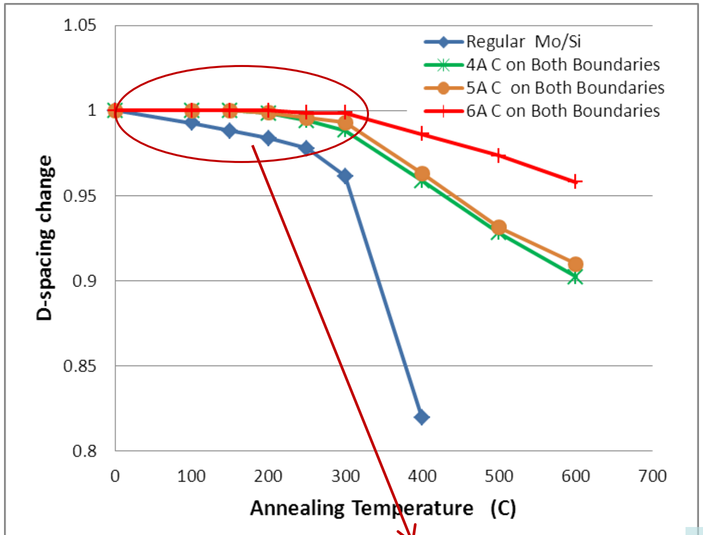
Saša Bajt

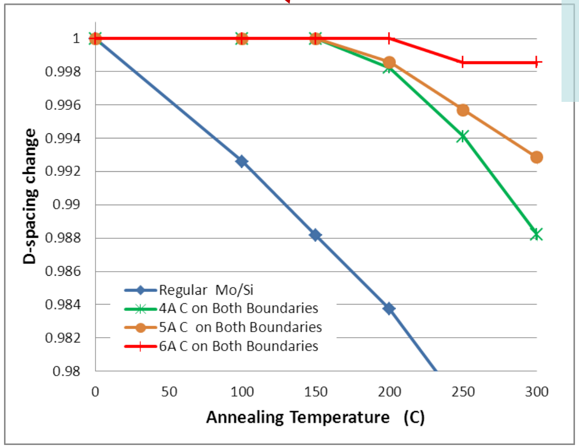
Lawrence Livermore National Laboratory

Rigaku

Barrier Layer: d-spacing change (Cu-K_α)

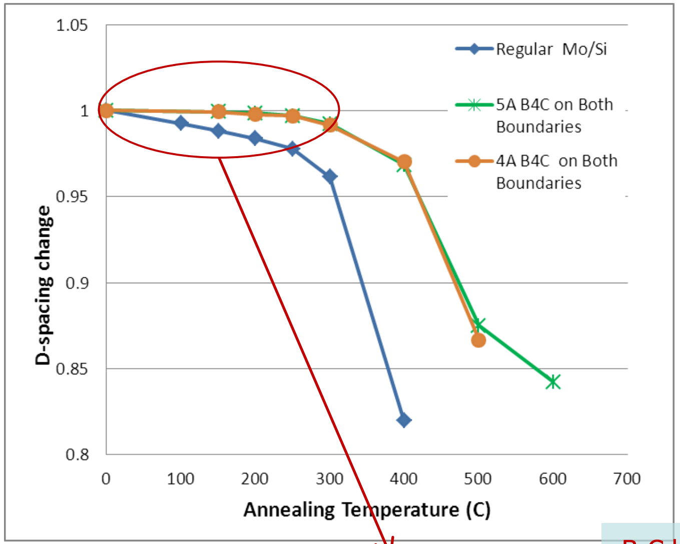
C barrier layer

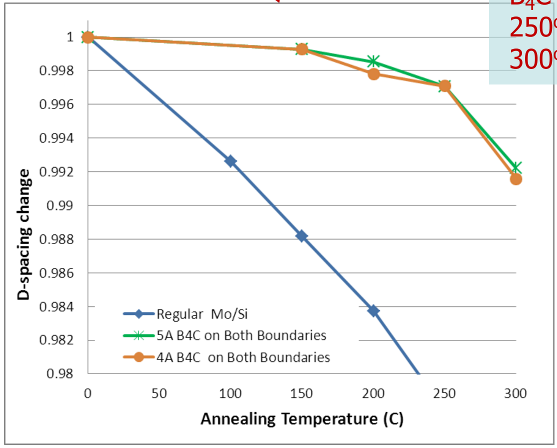




C barrier
250°C: <0.2% loss
300°C: <0.2% loss

B_4C barrier layer

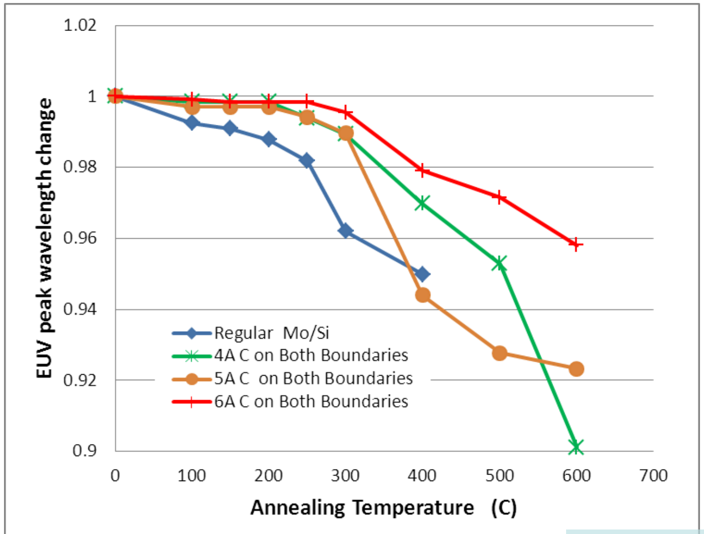


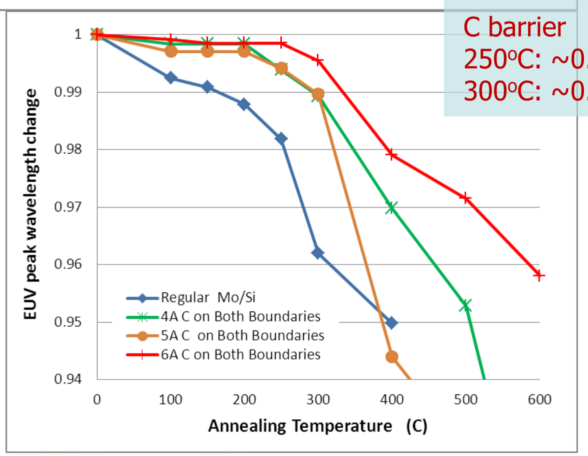


B_4C barrier
250°C: ~0.3% loss
300°C: ~0.8% loss

Barrier Layer: λ(peak) change

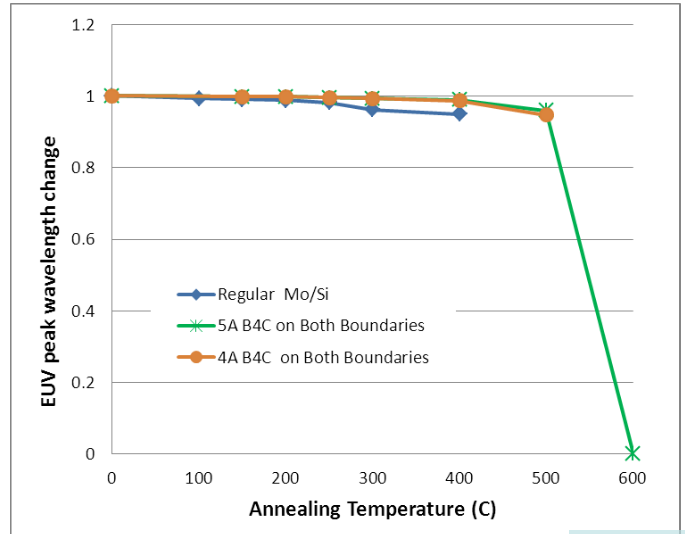
C barrier layer

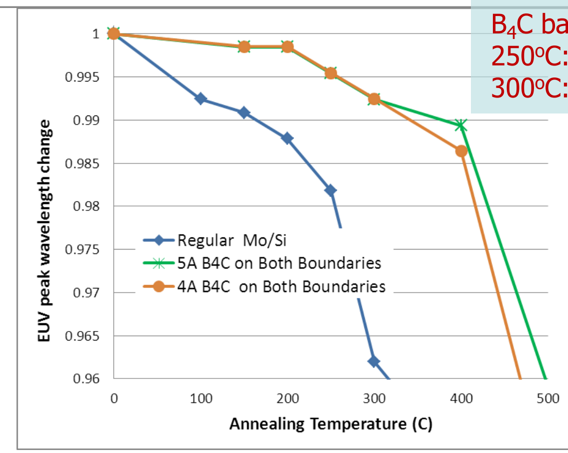




C barrier
250ºC: ~0.1%
300ºC: ~0.4%

B_4C barrier layer





B_4C barrier
250ºC: ~0.5%
300ºC: ~0.8%

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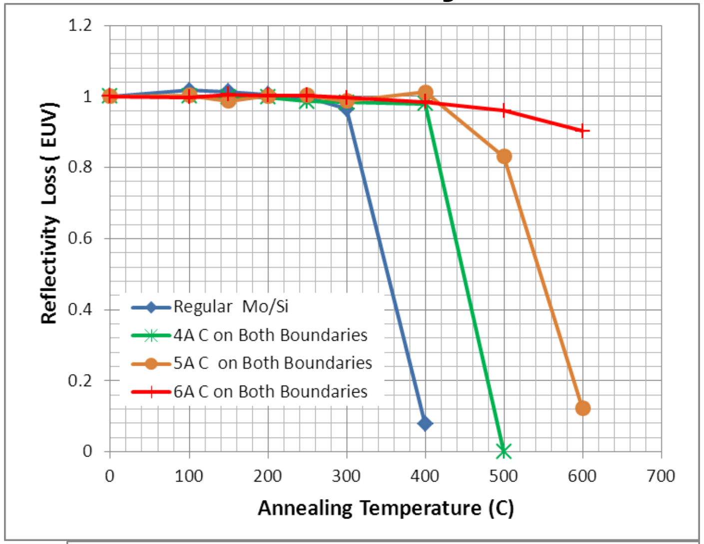
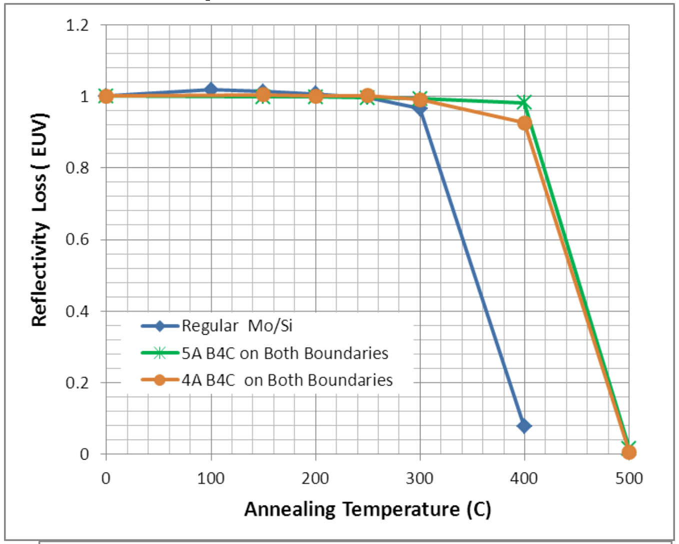
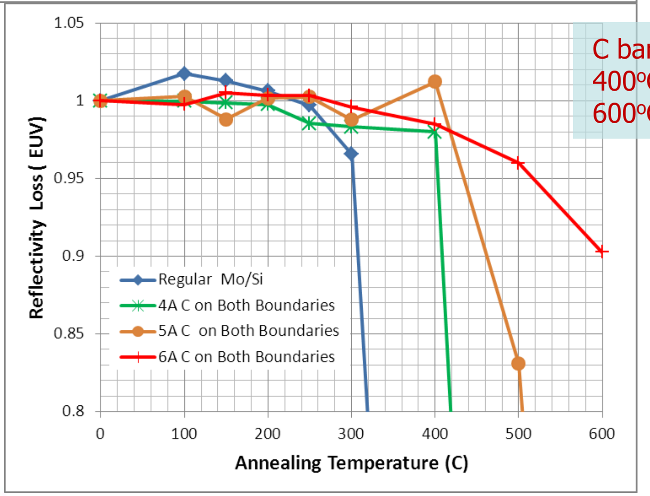
Barrier Layer: EUV reflectivity change

C barrier layer

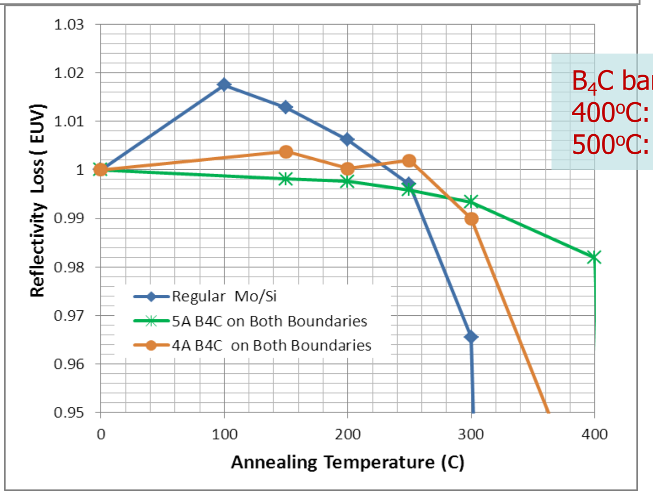
B_4C barrier layer





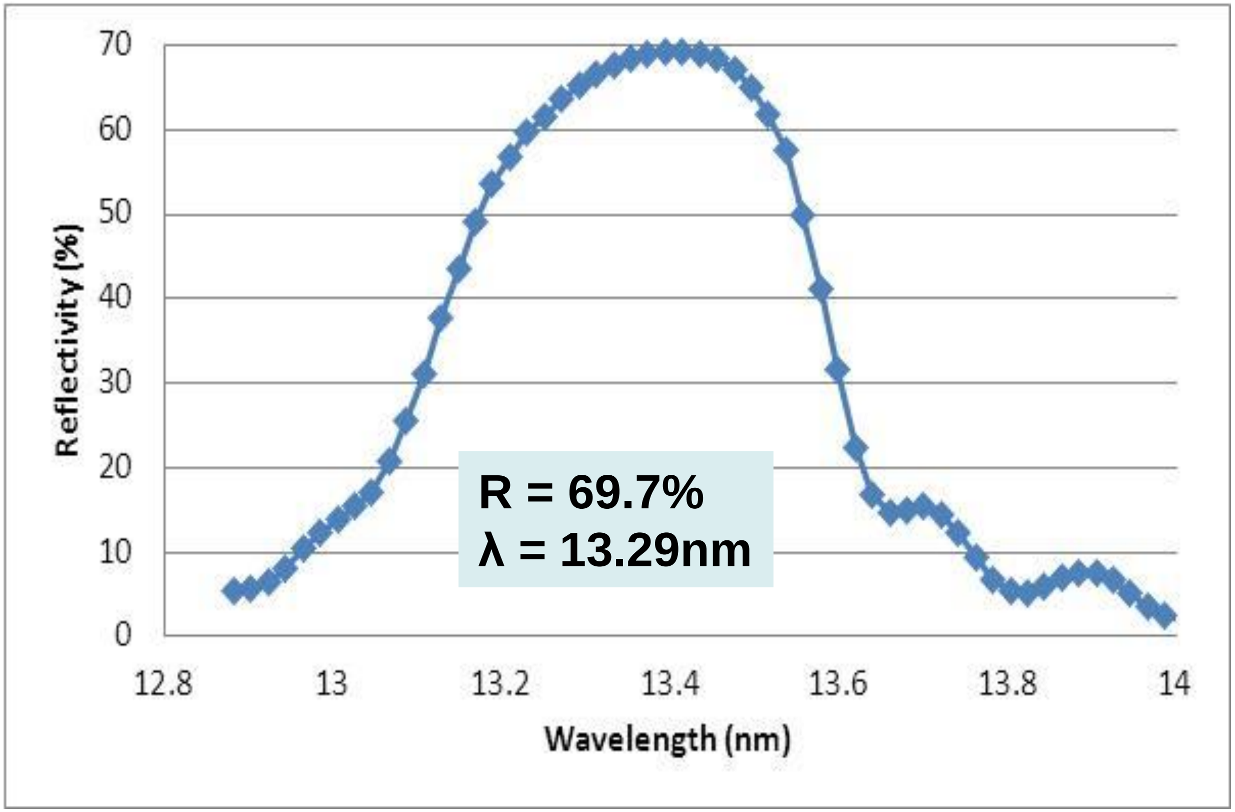


C barrier
400°C: <0% loss
600°C: ~10% loss



B_4C barrier
400°C: <2% loss
500°C: ~100% loss

EUV reflectivity of Mo/Si multilayer with barrier layers



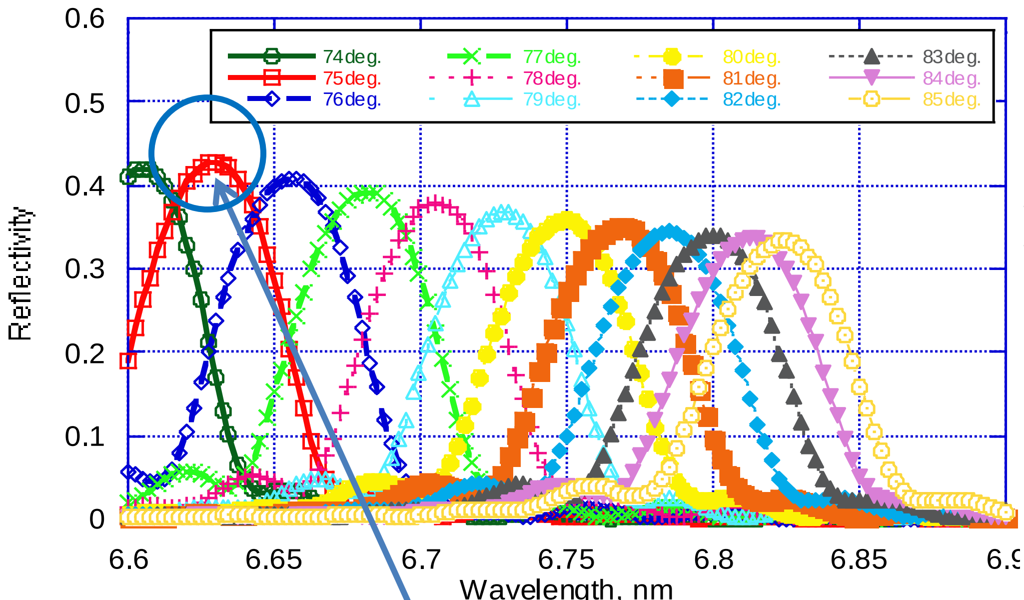
Measurements were done at NIST in June 2012

Measurements in 2 weeks after deposition.
The multilayer was stored in a typical room environment.

ML for 6.X nm

Previous year results

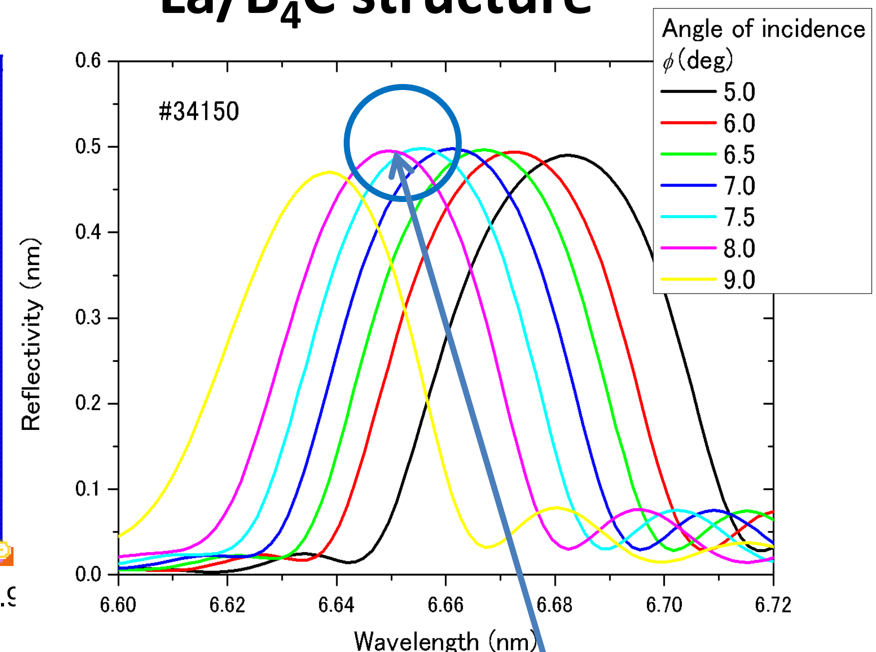
La_2O_3/B_4C structure



Measurements at CXRO, March 2011

R(max)=42.8% at ~6.63nm

La/B_4C structure



Measurements at New Subaru, May, 2011

R(max)=49.83% at ~6.656nm

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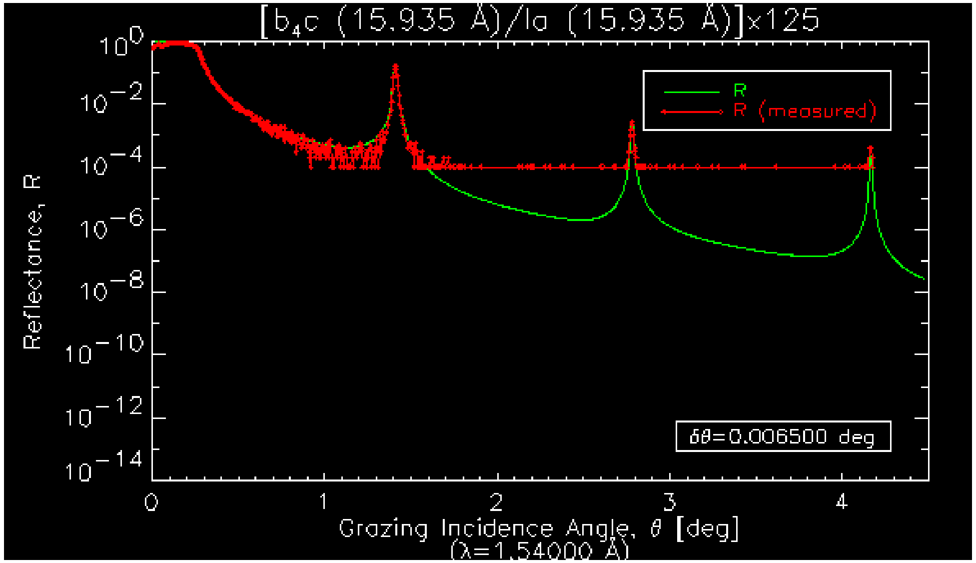
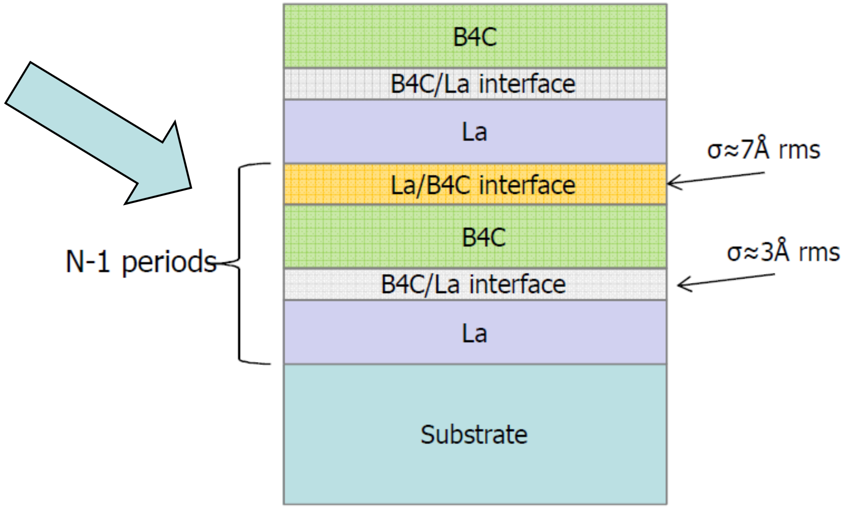
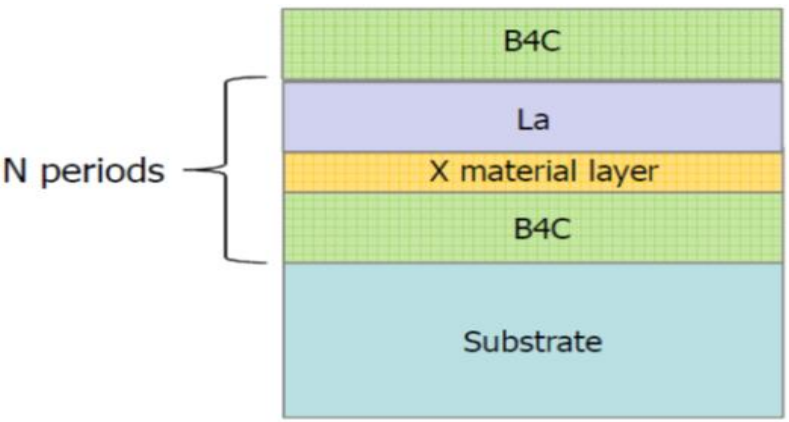
A typical La/B_4C structure

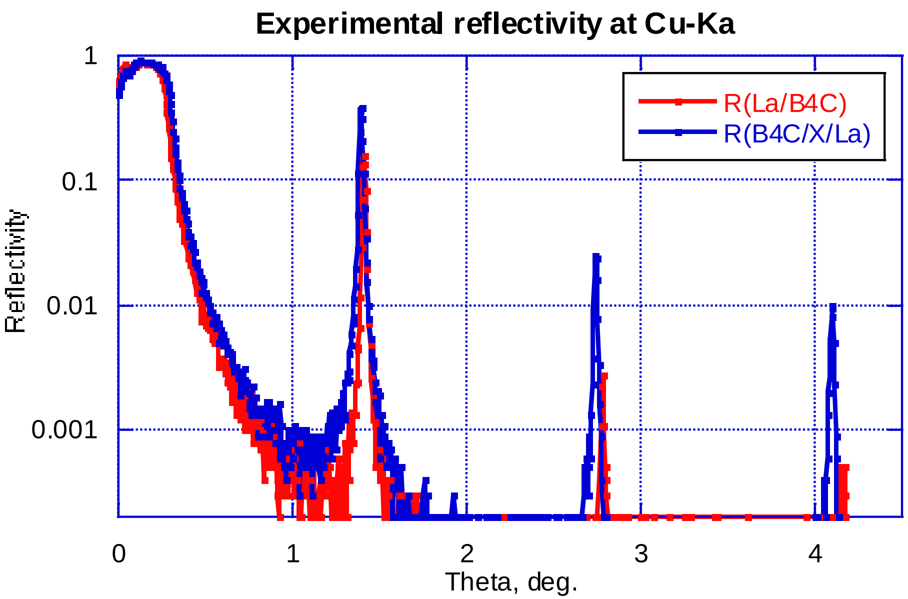
Cu-K_α (λ=1.54Å) fitting

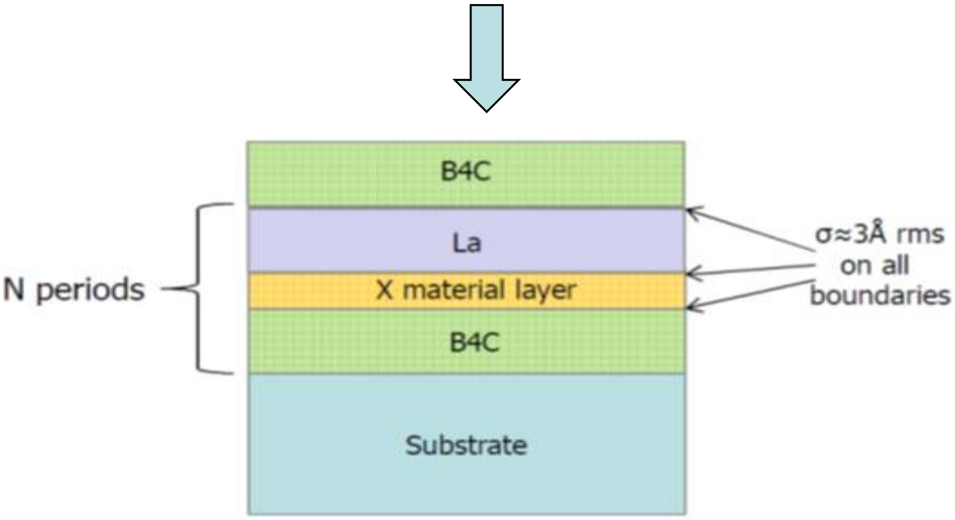




ML for 6.X nm

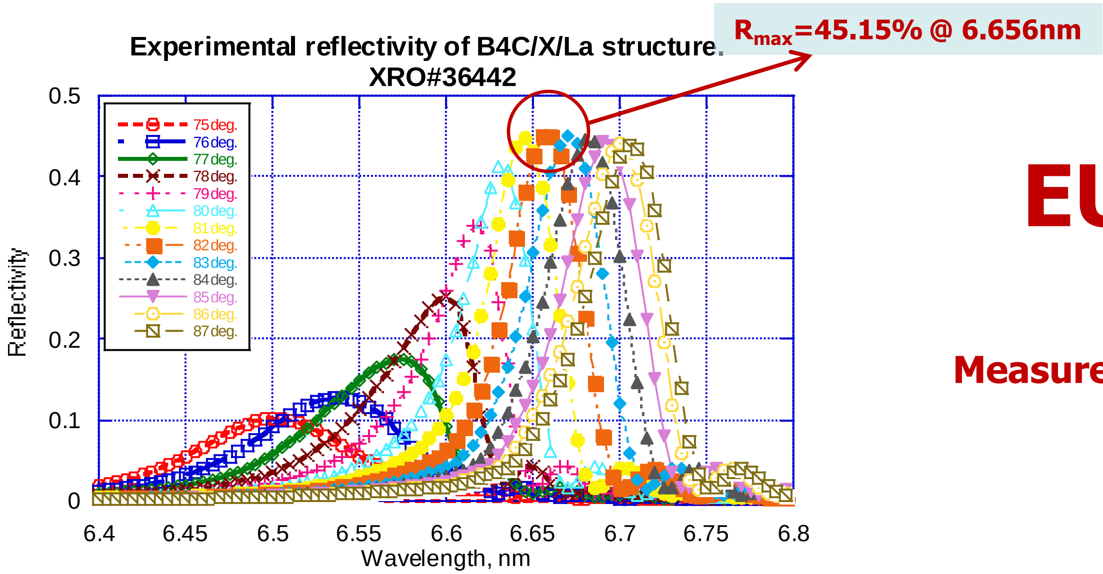






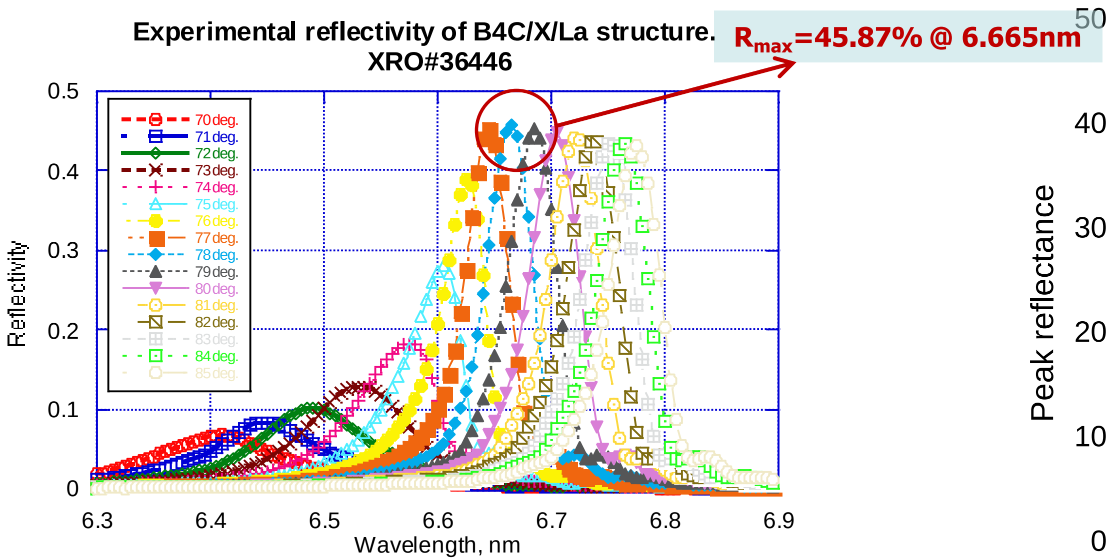
Barrier layer for La/B_4C structure

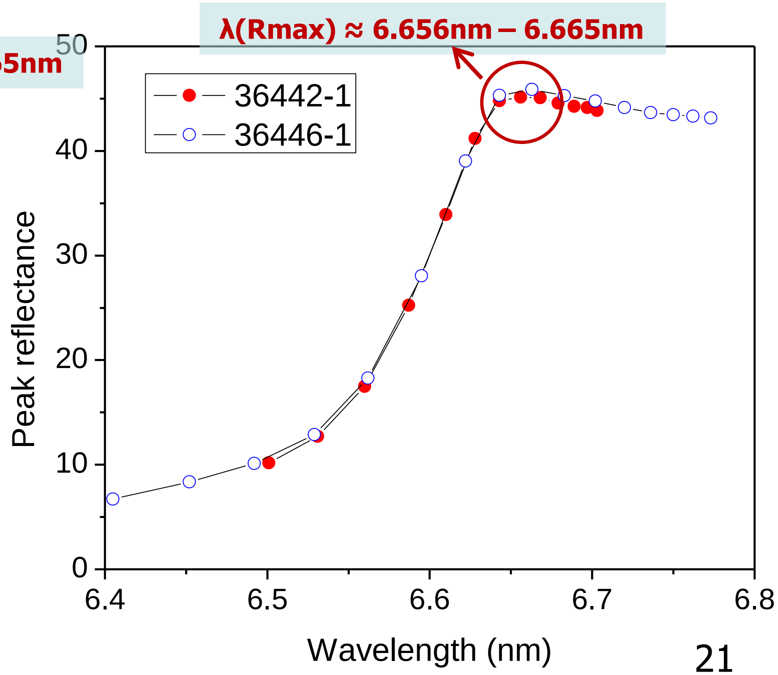
ML for 6.X nm



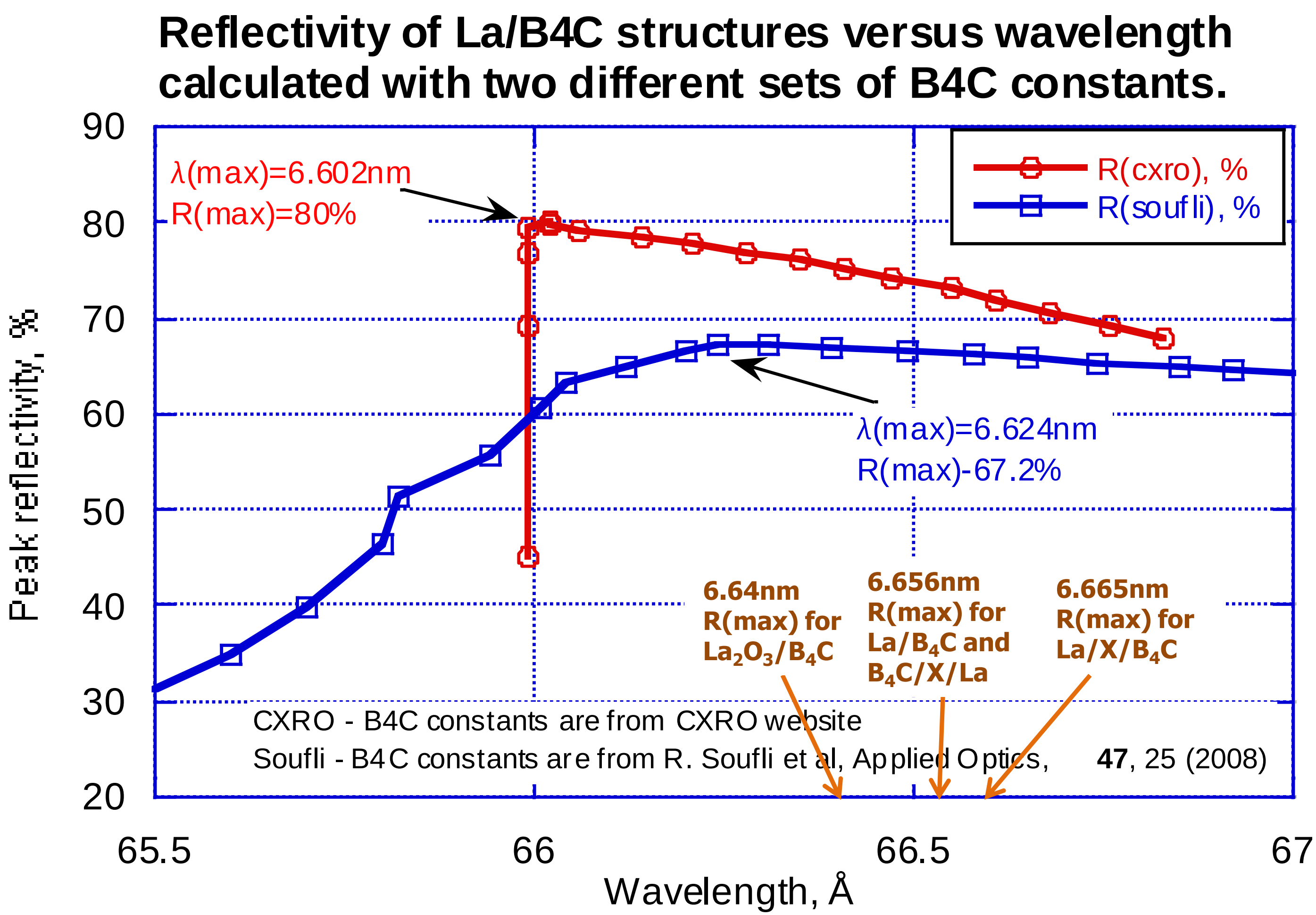
EUV reflectivity results

Measurements done at CXRO in May, 2012

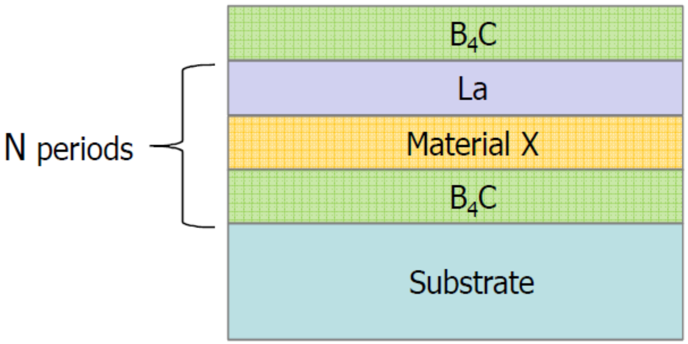


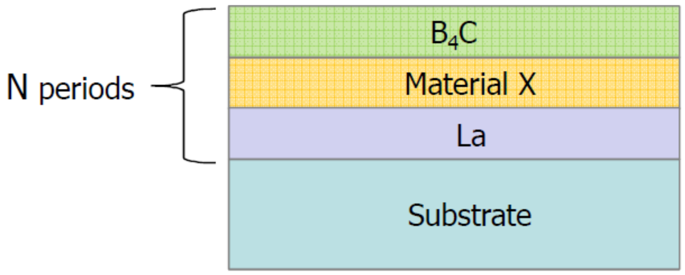


Optical constants and maximum reflectivity

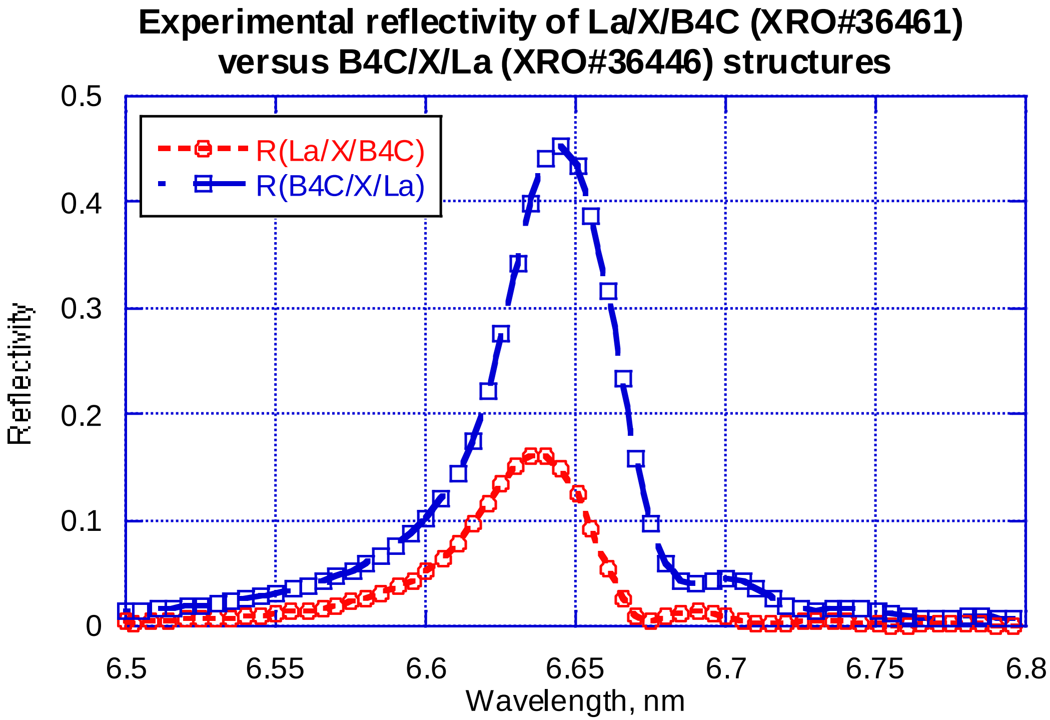


ML for 6.X nm

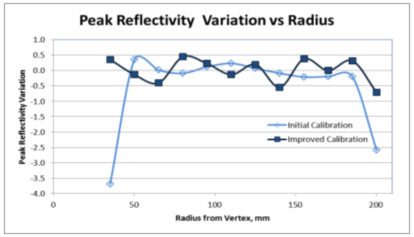


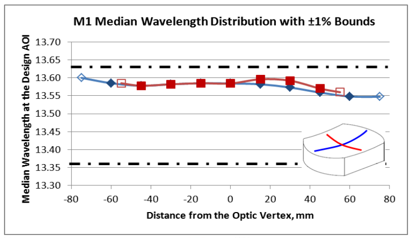


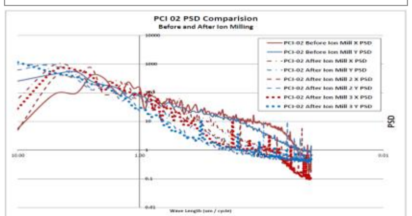
Barrier layer on B_4C or on La ?

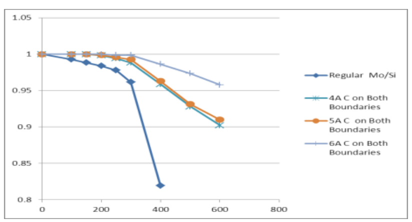


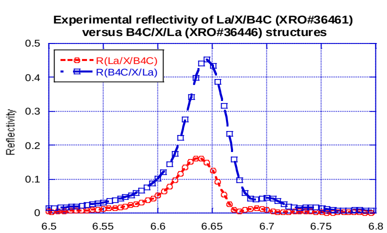
Conclusion











- **Collector optics**

  +/- 0.5% reflectivity variation across CA, R~67%

  +/- 0.25% λc variation at fixed radii

- **Illuminator optics**

  45 degrees off-axis ellipsoids

  < +/- 1% d-uniformity; R ≈ 66%

- **Substrates ion beam polishing**

  HSFR: smoothing from 10Å to 1.2Å

  MSFR: no change

- **Mo/X/Si/X ML thermal stability**
  - Δλ ~ 0.1% @ 250°C; Δλ ~ 0.4% at 300°C
  - ΔR ~0% loss at 400°C; ΔR ~ 10% loss at 600°C
  - R(max) = 69.7% at ~13.3nm

- **La/X/B_4C and B_4C/X/La performance**
  - Structural improvement based on Cu-K_α testing
  - ~46% for B_4C/X/La and ~16% for La/X/B_4C

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Thank you

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